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the rising of the land in this part of Spitzbergen. I shall also, where the rocks are hard enough for the purpose, bore along the shores as many watermarks as possible, to give in the future sure data for the settling of the same interesting question.

If it were possible to obtain a good pendulum we also would make pendulum observations, at least if the expedition remains in these regions during the winter.

P.S. The expedition will start from Gottenburg July the 15th.

VII. "Further Observations on the Spectra of the Sun, and of some of the Stars and Nebulæ, with an attempt to determine therefrom whether these Bodies are moving towards or from the Earth." By WILLIAM HUGGINS, F.R.S. Received April 23, 1868.

(Abstract.)

§ I. *Introduction.*

The author states that at the time of the publication of the "Observations on the Spectra of the Fixed Stars," made jointly by himself and Dr. W. A. Miller, Treas. R.S., they were fully aware that the direct comparisons of the bright lines of terrestrial substances with the dark lines in the spectra of the stars, which they had accomplished, were not only of value for the more immediate purpose for which they had been undertaken, namely, to obtain information of the chemical constitution of the investing atmospheres of the stars, but that they might possibly serve to reveal something of the motions of the stars relatively to our system. If the stars were moving towards or from the earth, their motion, compounded with the earth's motion, would alter to an observer on the earth the refrangibility of the light emitted by them, and consequently the lines of terrestrial substances would no longer coincide in position in the spectrum with the dark lines produced by the absorption of the vapours of the same substances existing in the stars.

The method employed by them would certainly have revealed an alteration of refrangibility as great as that which separates the lines D. They had, therefore, proof that the stars which they had examined, among others Aldebaran, α Orionis, β Pegasi, Sirius, α Lyræ, Capella, Arcturus, Castor, Pollux, were not moving with a velocity which would be indicated by such an amount of alteration of position in a line.

Since, however, a change of refrangibility corresponding to that which separates the components of D would require a velocity of about 196 miles per second, it seemed to them premature to refer to this bearing of their observations. The earth's motion, and that of the few stars of which the parallax has been ascertained, would make it probable that any alteration in position would not exceed a fraction of the change which would have been observed by them.

The author has since, for several years, devoted much time and labour to this investigation, and believes that he has obtained a satisfactory result.

He refers to Doppler, who first suggested that the relative motion of the luminous object and the observer would cause an alteration of the wave-length of the light; and to Ballot, Klinkerfues, Sonnche, Fizeau, and Secchi, who have written on the subject.

The author is permitted to enrich his paper with a statement of the influence of the motions of the heavenly bodies on light, and of some experiments made in an analogous direction, which he received in June 1867 from Mr. J. C. Maxwell, F.R.S.

It is shown that if the light of the star is due to the luminous vapour of sodium or any other element which gives rise to vibrations of definite period, or if the light of the star is absorbed by sodium-vapour, so as to be deficient in vibrations of a definite period, then the light, when it reaches the earth, will have an altered period of vibration, which is to the period of sodium as $V+v$ is to V, when V is the velocity of light and v is the velocity of approach of the star to the earth. Equal velocities of separation or approach give equal changes of wave-length.

§ II. *Description of Apparatus.*

A new spectroscope is described, consisting in part of compound prisms, which gives a dispersive power equal to nearly seven prisms of 60° of dense flint glass. Various methods were employed for the purpose of ensuring perfect accuracy of relative position in the instrument between the star spectrum and the terrestrial spectrum to be compared with it. A new form of apparatus, which appears to be trustworthy in this respect, was contrived. Many of the observations were made with vacuum-tubes or electrodes of metal, placed before the object-glass of the telescope.

§ III. *Observations of Nebulæ.*

The author states that he has examined satisfactorily the general characters of the spectra of about seventy nebulæ. About one-third of these give a spectrum of bright lines; all these spectra may be regarded as modifications of the typical form, consisting of three bright lines, described in his former papers.

Some of these nebulæ have been reexamined with the large spectroscope described in this paper, for the purpose of determining whether any of them were possessed of a motion that could be detected by a change of refrangibility, and whether the coincidence which had been observed of the first and the third line with a line of hydrogen and a line of nitrogen would be found to hold good when subjected to the test of a spreading out of the spectrum three or four times greater than that under which the former observations were made. The spectrum of the Great Nebula in Orion was very carefully examined by several different methods of comparison of its spectrum with the spectra of terrestrial substances.

The coincidence of the lines with those of hydrogen and nitrogen remained apparently perfect with an apparatus in which a difference in wave-length of 0·0460 millionth of a millimetre would have been detected. These results increase greatly the probability that these lines are emitted by nitrogen and hydrogen.

It was found that when the intensity of the spectrum of nitrogen was diminished by removing the induction-spark in nitrogen to a greater distance from the slit, the whole spectrum disappeared with the exception of the double line, which agrees in position with the line in the nebulæ, so that, under these circumstances, the spectrum of nitrogen resembled the monochromatic spectra of some nebulæ. It is obvious that if the spectrum of hydrogen were greatly reduced in intensity, the strong line in the blue, which corresponds to one of the lines of the nebular spectrum, would remain visible after the line in the red and the lines more refrangible than F had become too feeble to affect the eye.

It is a question of much interest whether the few lines of the spectra of these nebulæ represent the whole of the light emitted by these bodies, or whether these lines are the strongest lines only of their spectra which have succeeded in reaching the earth. Since these nebulæ are bodies which have a sensible diameter, and in all probability present a continuous luminous surface, we cannot suppose that any lines have been extinguished by the effect of the distance of the objects from us. If we had reason to believe that the other lines which present themselves in the spectra of nitrogen and hydrogen were quenched on their way to us, we should have to regard their disappearance as an indication of a power of extinction residing in cosmical space, similar to that which was suggested from theoretical considerations by Chéseaux, and was afterwards supported on other grounds by Olbers and the elder Struve.

It is also shown that at the time of the observations this nebula was not receding from us with a velocity greater than 10 miles per second; for this motion, added to the earth's orbital velocity, would have caused a want of coincidence of the lines that could have been observed. If the nebula were approaching our system, its velocity might be as much as 20 or 25 miles per second, for part of its motion of approach would be masked by the effect of the motion of the earth in the contrary direction.

§ IV. *Observations of Stars.*

A detailed description is given of the comparisons of the line in Sirius corresponding to F, with a line of the hydrogen spectrum, and of the various precautions which were taken against error in this difficult and very delicate inquiry. The conclusions arrived at are:—that the substance in Sirius which produces the strong lines in the spectrum of that star is really hydrogen; further, that the aggregate result of the motions of the star and the earth in space, at the time the observations were made,

was to degrade the refrangibility of the dark line in Sirius by an amount of wave-length equal to 0·109 millionth of a millimetre.

If the velocity of light be taken at 185,000 miles per second, and the wave-length of F at 486·50 millionths of a millimetre, the observed alteration in period of the line in Sirius will indicate a motion of recession between the earth and the star of 41·4 miles per second.

At the time of observation, that part of the earth's motion which was in the direction of the visual ray, was equal to a velocity of about 12 miles per second from the star.

There remains unaccounted for a motion of recession from the earth amounting to 29·4 *miles per second, which we appear to be entitled to attribute to Sirius.*

Reference is made to the inequalities in the proper motion of Sirius; and it is stated that at the present time the proper motion in Sirius in declination is less than its average amount by nearly the whole of that part of it which is variable, which circumstance may show that a part of the motion of the star is now in the direction of the visual ray.

Independently of the variable part of its proper motion, the whole of the motion which can be directly observed by us is only that portion of its real motion which is at right angles to the visual ray. Now it is precisely the other portion of it, which we could scarcely hope to learn from ordinary observations, which is revealed to us by prismatic observations. By combining both methods of research, it may be possible to obtain some knowledge of the real motions of the brighter stars and nebulæ.

Observations and comparisons, similar to those on Sirius, have been made on α Canis Minoris, Castor, Betelgeux, Aldebaran, and some other stars. The author reserves the results until these objects have been re-examined. It is but seldom that the atmosphere is favourable for the successful prosecution of this very delicate research.

§ V. *Observations of the Sun.*

The author has observed the sun with three distinct objects in view:—

1. He has sought to discover if the spectrum of the light from the less luminous part of the sun near the limb, differs in any respect from that of the light from the central parts of his disk.

2. He hoped to obtain a view of the red prominences visible during a solar eclipse by reducing the light from our atmosphere by dispersion; for, under these circumstances, if the red prominences give a spectrum of bright lines, these lines would remain but little diminished in brightness, and might become visible.

His observations in these two directions have been hitherto unsuccessful.

3. He proposed to seek to gain from an examination of the spectra of the umbræ and penumbræ of solar spots, some information as to the nature of these phenomena. He has successfully applied the large spectroscope, already described, to the light from the umbra of a spot.

His observations are in accordance generally with those communicated by Mr. Lockyer to the Royal Society.

The author describes the examination of a spot on April 15th, 1868. He shows that about three-fourths of the apparent light of the umbra came from that region of the sun, and the remaining fourth from the intervening illuminated atmosphere of the earth. He observed an increase of width in most of the dark lines of the solar spectrum. The lines C and F, due to hydrogen, did not appear stronger in the spectrum of the umbra. No new lines were detected, nor were any of those of the normal solar spectrum observed to be wanting in the spectrum of the light from the umbra. No bright lines were seen.

Some of the conditions of the solar surface are considered which the phenomena observed may be supposed to indicate.

A cooler state of the heated vapours by which the lines of absorption are produced would diminish the radiation from the gas itself, and so leave more completely uncompensated the absorption by the gas of the light from behind it. Though in this way an apparent increased intensity of the dark lines would result, the observations seem to suggest a state of the vapours connected with tension and temperature in which their power of absorption for each line embraces an increased range of wavelength. Some of the conditions under which this state of things may be brought about are discussed.

The absence of bright lines is not considered as conclusive of the complete absence of light in the umbra from luminous gas; for if there existed in the spot or above it the same vapours in a cooler state, the light would be almost wholly absorbed, and the feebler emanations of the cooler vapour might not do more than render less intense the dark gaps produced by the vapours in the stronger light of all refrangibilities which is evidently present.

What is the source of the light in the umbra which gives the continuous spectrum? May the dense and intensely heated gases, which probably form the inner substance of the sun, emit, in some cases, lines so greatly expanded as to form, when numerous spectra are superposed, a sensibly continuous spectrum? Dr. Balfour Stewart has suggested that, as gases possess a power of *general* absorption of light, a heated mass of gas, if sufficiently dense to be opaque or nearly so, would give a continuous spectrum as well as the spectrum of bright lines peculiar to it.

VIII. "On the Spectrum of Brorsen's Comet, 1868." By William Huggins, F.R.S. Received May 14, 1868.

In January 1866 I communicated to the Royal Society the result of an examination of a small comet visible in the beginning of that year*. I

* Proceedings of the Royal Society, vol. xv. p. 5.